Comparing Solar Sail and Solar Electric Propulsions for Propulsive Effectiveness in Deep Space Missions

Chen-wan L. Yen[1]
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109

ABSTRACT

A promise of new sail technology is generating renewed interest in solar sailing. Ultra light–weight carbon films with built-in stiffness for example is being developed with the partnership of JPL and Industry. It is predicted to result in a sail with very low area density (~2 g/m**2) with high temperature tolerance. There are many past solar sail mission studies suggesting the usefulness of solar sails for a gamut of planetary and space physics missions. However, that perpetual question of " how does the sail compare with the SEP or even NEP" among the NASA program evaluators has never been answered in any systematic way. This paper presents the results of a short study to respond to such an inquiry. NEP has the capability to thrust anywhere and uniquely suited for outer planet orbiters or large solar range missions. However, NEP has to be big (e.g. >100 KW) to be mass efficient, and it cannot be in the same class as SEP or sail as far as the launch vehicle requirement is concerned for modest payload missions. Thus Sail vs. SEP will be the subject of this comparison.

This study considered a set of NASA missions of general interest, as shown in Table 1. The goal of the study was to compare in a logical and uniform manner the effectiveness of each propulsive device (Sail or SEP) in performing the given set of missions. The study selected the use of a Delta II/7925 launch vehicle and set the same payload goal (net mass) of 500 kg for each to deliver. Then the flight time required by each device becomes the single performance discriminator. Although the methodology sounds simple enough, the issue of which technology levels are to be assigned for the comparison is not. There is no question that SEP technology is much more mature than Sail with a test flight DS1 still in progress. A small extrapolation from NSTAR technology would be an adequate representation of the SEP for the near term (2005-2010) applications. Even if prospect for a very light sail is imminent, a test flight to confirm the ability to deploy, control and perform thrusting is needed for the Sail to become a serious candidate. To enable the study to go forward, one parameter called sail loading; g = (sail propulsion system mass)/(sail area); can be used to represent the sail technology. The value of 10 g/m**2 and 5 g/m**2 are suggested by technologists to be appropriate technology levels at 2005 and 2010.

Figure 1 and 2 are examples of the plots created to evaluate the performance of flybys and rendezvous missions. Other performance analysis and the conclusions arrived at will be detailed in the paper.

Additional Author Information:

C.L. Yen:	Telephone:	(818) 354 4899
	Fax:	(818) 393-9815

[1] Member of Technical Staff, Navigation and Mission Design Section

E-mail: chen-wan.l.yen@jpl.nasa.gov

Table 1. Mission set of General Interests

Planetary
Fast Outer Planet Flybys
Outer Planet Flybys followed by Orbit Capture (orbiter)
Inner Planet Orbiters
Asteroid Rendezvous
Comet Rendezvous
Sample Returns from Small Bodies
Multiple Small Body Rendezvous
Space Physics
Solar Monitors at Various Solar Range and Earth Phasing
Solar Polar Orbiter
Interplanetary Medium Explorer
Interstellar Flight (>100 AU)

Figure-1. Flybys: Solar Range vs. Flight Time

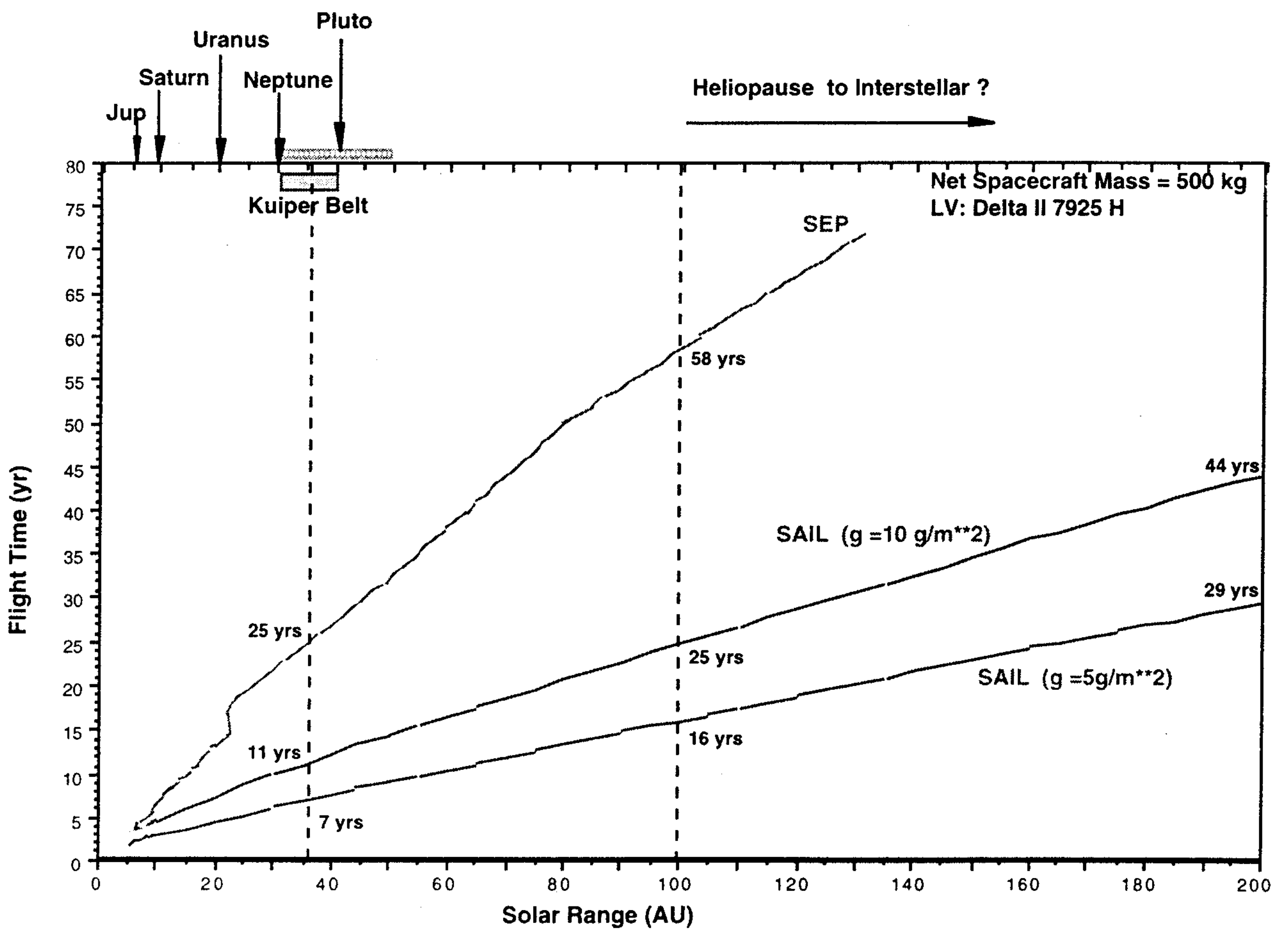

Figure-2. Rendezvous: Circular Orbit Radius vs. Flight Time